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RESEARCH MEMORANDUM

WIND-TUNNEL INVESTIGATION OF A SHIELDED TOTAL-PRESSURE TUBE AT TRANSONIC SPEEDS

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WIND-TUNNEL INVESTIGATION OF A SHIELDED TOTAL-PRESSURE TUBE AT TRANSONIC SPEEDS

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SUMMARY

The variation of total-pressure error with angle of attack of a shielded total-pressure tube having a curved venturi entry has been determined through an angle-of-attack range of 0° to 60° at Mach numbers ranging from 0.90 to 1.10. The tests were conducted in the Langley 8-foot high-speed tunnel.

The results of the tests showed that the critical angle (that is, the angle of attack at which the total-pressure error reaches a value of 1 percent of the impact pressure) varied from about 57° at a Mach number of 0.90 to about 56° at a Mach number of 1.10.

The critical angles determined in the present tests at Mach numbers of 0.90 and 0.95 agree to within 1.5° with the values obtained in a previous subsonic investigation at the same Mach numbers. From the results of both of these investigations the critical angle is shown to remain constant at about 63° over a Mach number range of 0.26 to 0.50; above a Mach number of 0.50, the critical angle decreases to the value determined at a Mach number of 1.10.

INTRODUCTION

The development of high-performance aircraft having the capability of maneuvering to high angles of attack at supersonic speeds has brought about the need for fixed or rigid total-pressure tubes which will measure total pressure correctly over a wide range of angle of attack throughout the Mach number range. In recognition of this need the National Advisory Committee for Aeronautics is conducting a series of wind-tunnel tests to determine the variation of total-pressure error with angle of attack of a number of total-pressure tubes at subsonic, transonic, and supersonic speeds.

Preliminary tests of 39 total-pressure tubes through an angle-of-attack range of $\pm 45^{\circ}$ at a low-subsonic speed were reported in reference 1. Subsequent tests of 20 of these tubes over an angle-of-attack range of $\pm 45^{\circ}$ at several supersonic speeds were presented in reference 2. The results of these tests showed that a shielded total-pressure tube having a conical venturi entry (Kiel design - reference 3) provided the greatest insensitivity to angle of attack. As a means of determining whether the range of insensitivity of this type of tube could be extended to higher angles of attack, additional tests (reference 4) were conducted on six variations of the basic Kiel design over a Mach number range of 0.26 to 0.95. These tests showed that the range of insensitivity of a shielded tube could be increased by about 50 percent by the use of a curved venturi entry, the shape of which was adapted from a design given in reference 5.

As an extension of the investigation of shielded tubes, further tests have been conducted at transonic speeds on the tube with the curved entry. This paper presents the results of these tests.

SYMBOLS

H	free-stream total pressure in subsonic flow or the total pressure behind a normal shock in supersonic flow
H'	total pressure measured by the total-pressure tube
ΔH	total-pressure error $(H' - H)$
p_s	stream static pressure
q_c	impact pressure $(H - p_s)$
M	stream Mach number
α	angle of attack of total-pressure tube, degrees

APPARATUS AND TESTS

A diagram of the shielded total-pressure tube which was tested in this investigation is shown in figure 1. The configuration of this tube is a modification of the Kiel design reported in reference 3. The present design differs from that of the Kiel tube in that the shape of the venturi entry is curved rather than conical and the interior of the shield is vented along the walls of the tube instead of directly to the

rear. This latter innovation was adopted in order to permit end-mounting of the tube on a horizontal boom and thereby avoid the vibration difficulties which had been encountered with the spindle-type mounting of the Kiel design.

The tests were conducted in the Langley 8-foot high-speed tunnel. The tube was mounted at the end of a sting support through an adjustable coupling. The angular deflection of the sting-coupling combination was such that the tube could be set at any angle between 0° and 60° and at the same time remain in close proximity to the center line of the tunnel. For each test run the tube was set to a given angle of attack by means of a remote-control mechanism and a cathetometer located outside the tunnel wall. These settings were made with the tunnel operating in order that the effects of sting deflection due to air loads might be eliminated.

For each setting of the tube, measurements were taken at Mach numbers ranging from 0.90 to 1.10. The total-pressure error was determined as the difference between the pressure measured by the total-pressure tube and free-stream total pressure as measured by a reference total-pressure tube located upstream from the test section. For those Mach numbers at which shock formed ahead of the test tube, corrections were applied for the total-pressure loss through the shock. Thus, the total-pressure errors at supersonic speeds are a function only of changes in angle of attack and, as such, are directly comparable with the data obtained at subsonic speeds. The impact pressure and Mach number of each test run were determined from total pressure as measured by the reference total-pressure tube and static pressure as measured by an orifice located in the test chamber.

The accuracy of the measurement of angle of attack was estimated to be within 0.1°. The accuracy of the total-pressure error $\Delta H/q_c$ was calculated to be of the order of 0.002. Values of the test Mach numbers were accurate to within 0.01.

RESULTS AND DISCUSSION

The results of the tests of the total-pressure tube at eight Mach numbers between 0.90 and 1.10 are presented in figure 2. For each Mach number the total-pressure error ΔH is given as a fraction of the impact pressure q_c and is plotted as a function of the angle of attack α. For consistency in fairing the data beyond 50°, a curve was arbitrarily drawn through the points at 55° and 60° on the assumption that the error varied as the square of the angle of attack (taken from the angle at which the error departed from zero).

As indicated by this figure the total-pressure error at each Mach number remains essentially zero for angles of attack up to about 50° and deviates to values of about $-0.03q_c$ at $\alpha = 60°$. In order to establish a criterion for comparing the performance of the tube at the various Mach numbers, the angle of attack at which the total pressure reached a value of 1 percent of the impact pressure has been chosen as the basis for comparison. This angle is called the "critical angle." The critical angle was found to have a value of 57.1° at $M = 0.90$ and 55.6° at $M = 1.10$.

The critical angles as determined from the data shown in figure 2 have been plotted as a function of Mach number in figure 3. Included in figure 3 are the results of tests of the same total-pressure tube at subsonic speeds (reference 4). It will be noted that the values of the critical angle as determined by the present tests at $M = 0.90$ and 0.95 agree to within 1.5° with the data from the subsonic tests at the same Mach numbers. From the results obtained from both of these investigations, the critical angle is shown to remain constant at about 63° over a Mach number range of from 0.26 to 0.50; above $M = 0.50$ the critical angle decreases to a value of about 56° at $M = 1.10$.

CONCLUDING REMARKS

Transonic wind-tunnel tests of a shielded total-pressure tube having a curved venturi entry have been conducted through an angle-of-attack range of 0° to 60° at Mach numbers ranging from 0.90 to 1.10.

The results of the tests showed that the critical angle (that is, the angle of attack at which the total-pressure error reaches a value of 1 percent of the impact pressure) varied from about 57° at a Mach number of 0.90 to about 56° at a Mach number of 1.10.

The critical angles determined in the present tests at Mach numbers of 0.90 and 0.95 agree to within 1.5° with the values obtained in a previous subsonic investigation at the same Mach numbers. From the results of both of these investigations the critical angle is shown to remain constant at about 63° over a Mach number range of 0.26 to 0.50; above a Mach number of 0.50, the critical angle decreases to the value determined at a Mach number of 1.10.

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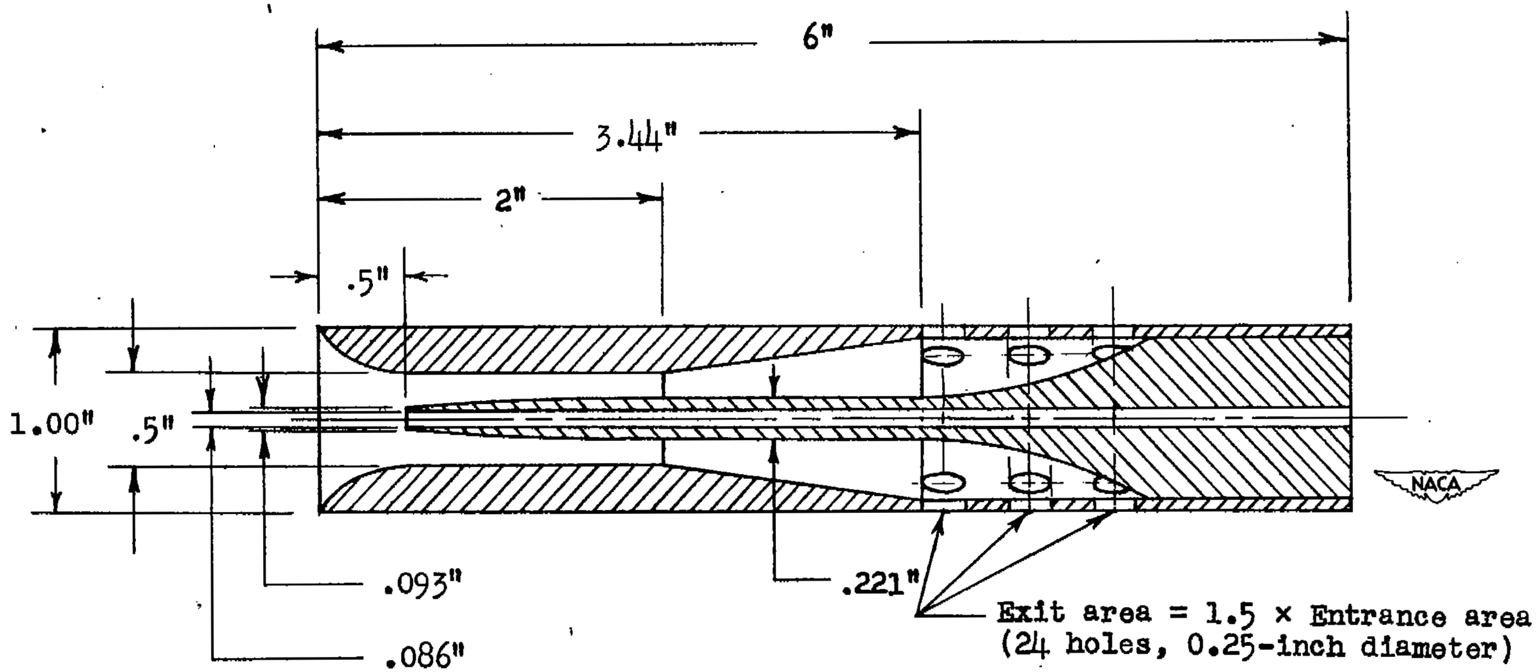

Figure 1.- Section view of shielded total-pressure tube.

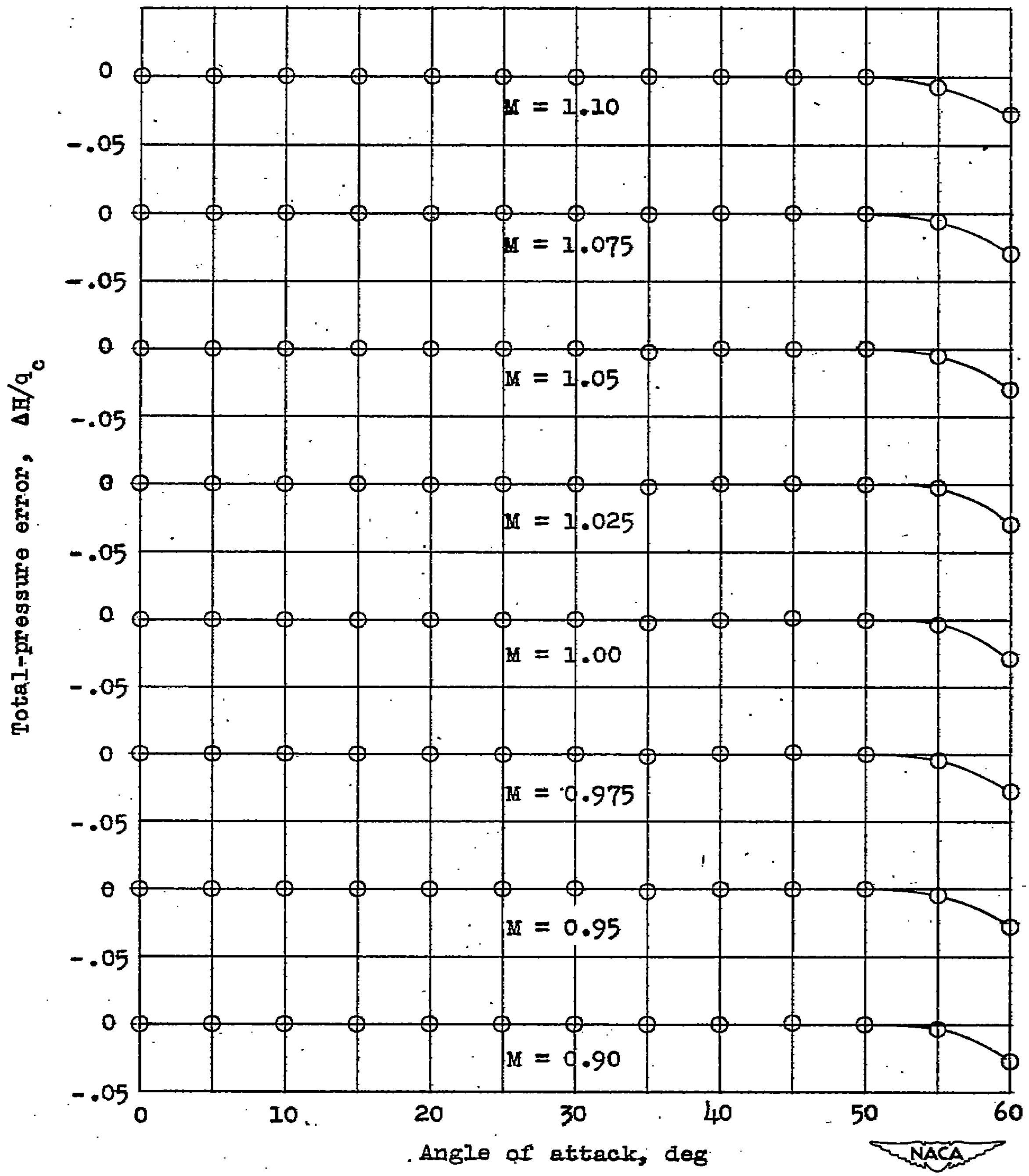

Figure 2.- Variation of total-pressure error with angle of attack at Mach numbers from 0.90 to 1.10.

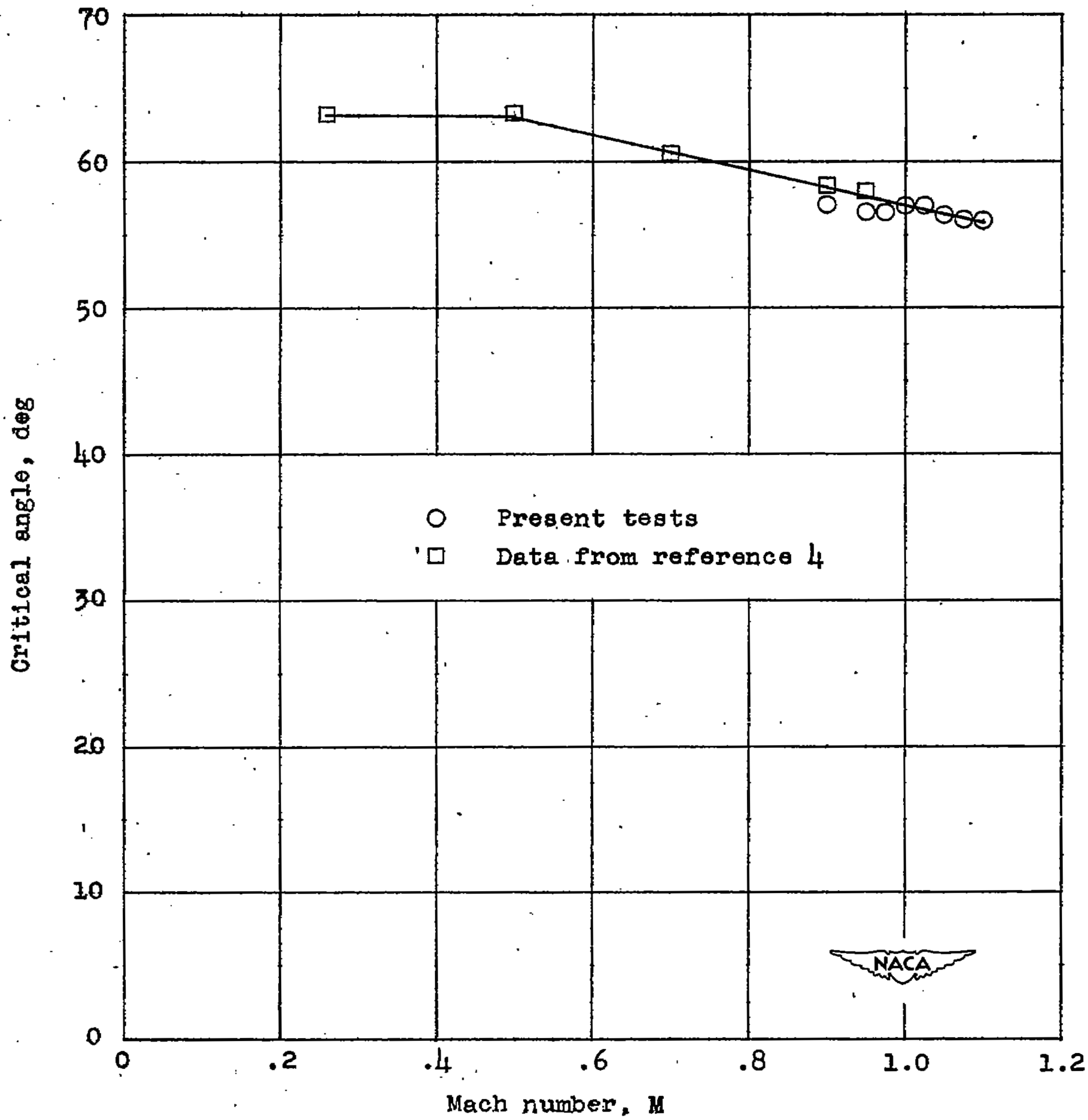

Figure 3.- Variation of critical angle with Mach number.

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